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Workload and Stress of Crews Operating Future Manned Vehicles

by Bruce S. Sterling, Chuck H. Perala, and Stephen F. Blaske

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14. ABSTRACT

This study examined workload and stress of crews operating future manned vehicles during virtual and live simulation and varied threat conditions. The effects, for live simulation only, of autonomous driving, crew position, and driving speed on workload and stress were also examined. Because of the small number of participants, only descriptive statistics were used. Results suggest that for the task of operating a vehicle and searching for and discriminating between dismounted non-combatants and enemy forces, live simulation was more stressful. The two levels of threat for enemy forces did not seem to substantially affect workload or stress, perhaps because the task loads under the two threat levels were not sufficiently different. Autonomous driving did not reduce workload or stress, particularly for the driver. Higher stress levels in the autonomous driving condition suggests that the implementation of autonomous driving in the CAT (Crew Integration and Automation Test Bed) vehicle was not appropriate for a scouting mission that required a precise level of speed control. There was also evidence of the gunner offloading work to the driver during autonomous driving. The gunner had higher workload (and to a lesser extent stress) than did the driver, especially in the higher threat condition where the gunner's responsibilities were greater. Higher speed driving also resulted in higher stress and workload.

15. SUBJECT TERMS

CAB; crew-aiding behavior; decision aids; target prioritization

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1. Introduction

1.1 Project Background

Evaluating Soldiers who are operating future force technology in a live environment is very resource intensive. Live evaluations involve the use of ranges, vehicle platforms for mounting the user interface, numerous test personnel, use of petroleum, oils, and lubricants (POL), plus safety and weather considerations. Evaluation of future force technology in virtual simulation is less resource intensive. It can be performed in an existing battle laboratory setting with a re-configurable vehicle with only changes in software, and it can involve fewer test personnel and no POL, weather, or safety considerations. If the virtual evaluation yields similar results to the live in terms of workload and stress, considerable cost savings could be achieved in determining MANPRINT (manpower and personnel integration) requirements. If the difference is substantial, then these data could be used in the development of algorithms for use in battle laboratory simulations and other models to emulate live versus virtual performance degradation.

Soldiers in the future force (as well as the current force) will have different types of missions. At times, Soldiers may perform reconnaissance or locate persons of interest, whereas in other situations, Soldiers may be responsible for locating persons of interest and protecting against dismounted personnel who constitute a threat. Our intent was to determine if workload during either of these missions seemed to excessively tax the ability of future Soldiers to perform the missions.

One automation tool that may assist Soldiers with multiple tasks is autonomous driving, that is, the capability of a vehicle to follow a pre-set route with little or no driver intervention. We wanted to determine whether this technology could reduce workload and stress, freeing crew members to perform other duties.

Workload and stress vary by duty position. For example, drivers and vehicle commanders may have different levels of workload and stress. Mitchell, Samms, Glumm, Krausman, Brelsford, and Garrett (2004), using the validated workload model Improved Performance Research Integration Tool (IMPRINT), found that the Mounted Combat System (MCS) driver had the most instances of high workload of any crew member, and all these were related to the primary activity of driving. Our goal was to determine if workload for either position exceeded Soldier's abilities.

Vehicle speed will likely affect workload and stress. Speed often affects survivability since a faster moving vehicle is a more difficult target and can leave danger areas more quickly. However, it is logical to assume that higher speeds increase workload and stress of crew members. Our intent was to determine if higher speeds represented unacceptable increases in workload and stress.

This joint effort between the U.S. Army Research Development and Engineering Command (RDECOM) and the U.S. Army Training and Doctrine Command Unit of Action Maneuver Battle Laboratory (UAMBL) was in support of the Crew integration and Automation Test Bed (CAT) Advanced Technology Demonstration (ATD) program, or CAT-ATD. Other experiments concerning future combat vehicles investigated capabilities related to human-robotic interactions and fire control technologies developed under the Technology for Human-Robotic Interaction in Soldier-Robot Teaming (HRI) and Fire Control Node Engagement (FC-NET) Army technology objectives (ATOs).

Specifically, Experiment 1 examined how Soldier decision aids (called crew-aiding behaviors or CABs) designed to automatically plan routes, observations posts (OPs), and firing positions affected Soldier workload and performance in terms of speed and accuracy. In Experiment 1, Soldiers planned a road march and tactical movement, with and without CABs. Experiment 1 was performed in a stationary virtual simulator described in section 2. Preliminary results suggested that the CABs reduced workload and increased planning speed.

Experiment 2 examined how autonomous driving affected Soldier workload and performance in the re-planning of a route from a moving vehicle, while local security was maintained. Soldiers re-planned a tactical movement while moving and maintaining local security from a CAT vehicle (described in section 2) during manual and autonomous driving. Preliminary results suggested that autonomous driving decreased workload.

Experiment 4[1] examined how a target prioritization CAB affected Soldier workload and performance. Soldiers prioritized targets and selected weapons and ammunition with and without CABs. This experiment was also performed in a stationary simulator. Results showed that the CABs reduced workload and substantially deceased time to prioritize targets, select weapons, and select ammunition.

RDECOM-UAMBL Experiment 06 (RUX06) is discussed in detail by Nunez (2006). These efforts incorporated UAMBL virtual environment capabilities with live tactical elements to produce realistic simulated battlefield scenarios. For example, “live” experiments were conducted with actual vehicles and systems on vehicle ranges 9 and 10 at Fort Knox, Kentucky. “Virtual” elements were conducted in vehicle mock-ups with computer-simulated imagery in UAMBL building 2001 at Fort Knox. Communications and battlefield situational awareness (SA) were updated and presented in near real time between the virtual and live elements.

1.2 Research Objective

This research had five objectives. The first was to compare workload and stress during live and virtual simulation. The second was to compare workload and stress during varying threat conditions (e.g., locating personnel of interest versus locating personnel of interest plus defending against dismounted threats). However, the differentiation of these conditions was compromised

[1]Experiment 3 was not conducted because of time constraints.

since Soldiers were not told whether threat personnel would be present on a given run. The third (in the live vehicle only) was to examine the effects of autonomous driving on workload and stress. The fourth (in the live vehicle only) was to examine the effects of duty position on workload and stress. The fifth and final objective (in the live vehicle only) was to examine the effects of vehicle speed on workload and stress.

2. Method

2.1 Apparatus

2.1.1 ACRT Simulator

The Advanced Concepts Research Tool (ACRT) shown in figure 1 is a reconfigurable simulator and was used in this experiment to emulate an MCS vehicle in the Future Combat System (FCS) family of systems. Each of the three ACRTs had three crew positions: vehicle commander, driver, and gunner. The vehicle commander sat in the rear position, and the gunner and driver sat in the front. Each position had two screens available to it. One screen could be used to display the common situational map, while the other screen could display a gunner's site, a driver's indirect driving view, or a screen showing a view from an unmanned ground or aerial vehicle's camera. There were also three screens at the front of the vehicle to emulate viewing ports at the front of the vehicle. The two front positions had driving controls (brake and gas pedals, steering yoke) and gunner controls (a yoke to control direction and elevation of the main gun, laser switch, and firing switch).

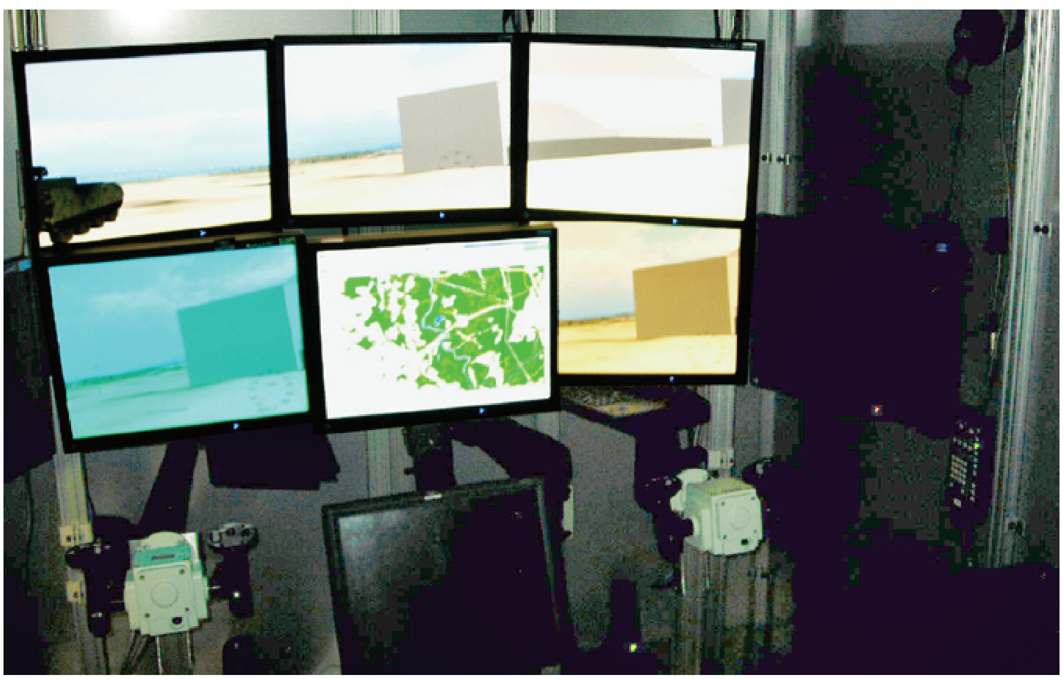

Figure 1. Reconfigurable ACRT simulator.

2.1.2 Crew Integration and Automation Test Bed (CAT) Vehicle and Simulator

The CAT Soldier-in-the-loop (SIL) interface (see figure 2) consisted of three vertically oriented liquid crystal displays situated in an arc in front of a seated participant. Each display was divided in two, horizontally, with information on each of the six "screens" provided from various computer systems, which were transparent to the SIL operation and the participant. One type of information that could be displayed on the CAT SIL was a map of the area of operation, with map tools such as zoom and operational graphics. Another type of information available was unmanned vehicle (UV) control. The UV control information available included the types of UVs available, their status, and a camera view from one of the UVs being controlled. A third type of information was target acquisition and reports. Soldiers could use this view to engage targets and to send or display reports received from others. A drive panel could also be selected in order to see the views from front and rear cameras of one's own platform, as well as various gauges involved in driving (e.g., speed, compass direction, etc.).

Figure 2. CAT SIL (MCS) crew station.

Various types of information could be manipulated by buttons and menus. For instance, one could display a driving camera view and UV control information on one of the three panels or a driving camera view and map information on one of the three panels. The hand controls consisted of yokes that could be used for steering, and switches used to "laze" (i.e., emit coherent light at) and fire at targets. The foot pedals could be used for acceleration and braking of one's own platform. Since the live vehicle had only two crew positions available, there was one CAT simulator crew

position for the platoon leader in building 2001 at Fort Knox. There were two CAT crew positions (driver and gunner) in a live vehicle CAT Stryker on a range at Fort Knox. Combined, these three crew positions simulated the three-Soldier crew of an FCS MCS vehicle. However, both the platoon leader and the other two crew members reported that this positioning of the platoon leader in a separate location tended to psychologically isolate him from the crew.

2.2 Measures

2.2.1 Workload

To measure subjective self-ratings of perceived workload, the National Aeronautics and Space Administration (NASA)-Task Load Index (TLX) was used. The NASA-TLX (Hart & Staveland, 1988) is a multi-dimensional rating procedure that derives an overall workload score based on ratings on six subscales. The subscales include Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration. Each subscale consisted of 20 points, for a total possible workload of 120. Ratings were collected on the questionnaire. This instrument is shown in appendix A.

2.2.2 Stress

One-item rating scales measuring perceived physical stress level and mental stress level each on a ten-point scale were used. The scales are shown in appendix A.

2.3 Participants

Twelve active-duty male Soldiers volunteered for this experiment. One Soldier was a Captain (O3), seven Soldiers were Sergeants First Class (E7), and four Soldiers were Staff Sergeants (E6). Military occupational specialties were primarily M1 Armor Crewmen (19K). Nine participants were 19K, one 19D (Cavalry Scout), one 14E (Patriot Fire Control Enhanced Operator), and one 25B (Information Systems Operator-Analyst). Each vehicle, live and virtual, had a three-person crew: driver, gunner, and vehicle commander; personnel were randomly assigned to each vehicle. The driver was responsible for driving and scanning for personnel of interest or threats. The gunner was responsible for scanning for personnel of interest or threats, engaging threats, and engaging beyond line of sight (BLOS) targets. The platoon leader was responsible for assigning BLOS targets to crews and communicating with crews and the troop commander (seated at a nearby computer). In the live vehicle, the vehicle commander (also platoon leader), was physically located in a virtual CAT workstation in building 2001 and communicated with his crew via radio. Because of the very small sample size, only descriptive statistics were used in this report.

2.4 Training

Participants in the ACRTs received brief training in operating the software to control the SA interface (maneuver command and control or MC2) and driver and gunner controls. The participant at the CAT SIL crew station (i.e., the platoon leader) had received training in a prior

experiment in how to use the software to plan and was given a brief refresher about the system. Participants in the CAT Stryker were also trained in driving and gunning functions in a prior experiment and were also given refresher training and a safety briefing. Although no criterion-based test was used, experimenters ensured that participants acquired a baseline level of proficiency before the trials began.

2.5 Procedures

Participants were given an overview of the experiment and were familiarized with the surveys. Baseline measures of workload and stress were taken only in the virtual condition because of a miscommunication in the field. For the baseline stress level, participants were asked to rate how they felt "right now," immediately before the start of the experimental trials. For baseline work-load, participants were asked to rate the workload experienced in driving to work that morning. We chose this task because it was a relatively simple (presumably) low-workload task that provided a point of reference against which the reported workload of other tasks could be compared. Participants were then trained or given refresher training in operating their assigned work station. Participants then conducted a total of five trials.

Two trials were conducted on the first day of the experiment; the first involved identifying persons of interest (non-combatants) only, and the second involved identifying non-combatants and engaging dismounted threat teams consisting of two enemies with a rocket-propelled grenade (RPG). On the second day, three experimental trials were conducted; the first involved non-combatants and RPG teams, and the second involved non-combatants only. The third involved non-combatants and RPG teams. After each experimental trial, participants completed workload, stress, and SA surveys.

For the two crew members in the live CAT Stryker, the first trials on both days involved manual driving (using indirect vision), while the second trials involved autonomous driving. The third trial on day 2, which used manual driving, was at 20 miles per hour (mph). The other four trials were at 12 mph. A summary of trials and conditions is presented in table 1.

During all trials, the MCS platoon maneuvered along a route to support an over-watch position held by the reconnaissance troop. The MCS platoon was directed to engage BLOS targets detected by the reconnaissance troop and relayed by the troop commander to the MCS platoon leader, while maintaining local security and conducting a battle damage assessment (BDA). However, since this was constant in all trials, it was not considered a factor in differences in workload among the trials.

Table 1. Summary of trials and conditions.

Trial	Live	Virtual
1	Non-combatants only – Manual driving – 12 mph	Non-combatants only
2	Non-combatants and Enemy – Autonomous driving - 12 mph	Non-combatants and Enemy
3	Non-combatants and Enemy- Manual driving – 12 mph	Non-combatants and Enemy
4	Non-combatants only – Autonomous driving – 12 mph	Non-combatants only
5	Non-combatants and Enemy – Manual driving – 20 mph	Non-combatants and Enemy

2.6 Analyses

Because of the small number of participants and the inability to counterbalance conditions, only descriptive statistics were used during the analysis. Means for workload and stress level were compared for live versus virtual simulation; mission (baseline, non-combatants only, non-combatants and enemy); manual versus autonomous driving mode (live vehicle only); crew position (live vehicle only); and speed (live vehicle only).

3. Results

3.1 Workload

3.1.1 Virtual Versus Live Simulation and Mission

Because there was a slight difference (interaction) between live and virtual simulation in how mission affected workload, the analyses for live versus virtual simulation and type of mission were combined. Tables 2 and 3 show the data for workload by type of simulation and mission.

Workload in the virtual simulation (see table 2) was very light, only reaching about 16% (19.21 of a possible 120) of total possible workload. Conversely, workload in the live simulation mission (see table 3) was considerably higher, reaching about 46% (55.50) of total possible workload. Figure 3 provides a comparison between virtual and live simulation across missions.

Table 2. Workload in virtual simulation by mission.

Mission	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Baseline (n=16)	2.25	2.25	2.00	6.94	3.88	2.06	19.38
Non-combatants only (n=14)	2.29	1.86	2.07	7.14	1.79	4.07	19.21
Non-combatants and Enemy (n=19)	1.79	1.63	2.05	6.37	1.68	2.74	16.25

Table 3. Workload in live simulation by mission.

Mission	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Baseline	NA	NA	NA	NA	NA	NA	NA
Non-combatants only (n=4)	7.50	4.50	11.50	15.00	13.00	4.00	55.50
Non-combatants and Enemy (n=4)	9.50	5.75	7.75	15.25	12.00	5.25	55.50

There were relatively minor differences between missions during virtual and live simulation. In the virtual simulation, overall workload for the higher threat condition (where RPG teams were present) was actually slightly lower than for any other condition, including baseline. However,

since participants were not aware of whether threats were present until and unless they encountered them, the tasks in both threat conditions (i.e., scan for threats versus persons of interest) were quite similar. The subscales of mental, physical, performance, and effort workloads were lower for the higher threat condition than any for other condition. In the live condition, overall workload was the same during lower and higher threat conditions. Mental, physical, and frustration workloads were at least a point higher in the higher threat condition, while temporal and effort workloads at least a point higher in the low threat condition. Figure 4 provides a comparison between each mission type across each of the six subscales of workload.

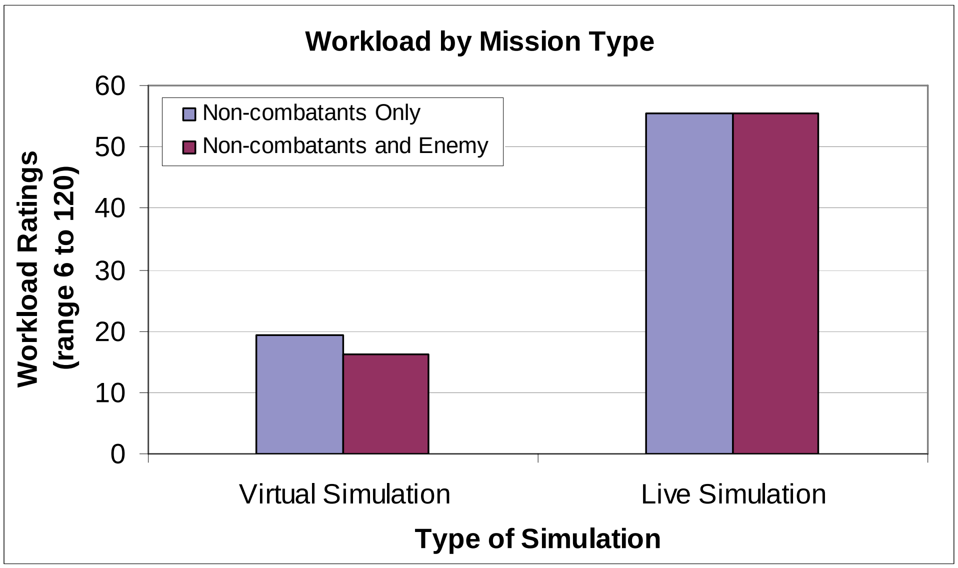

Figure 3. Workload by mission type.

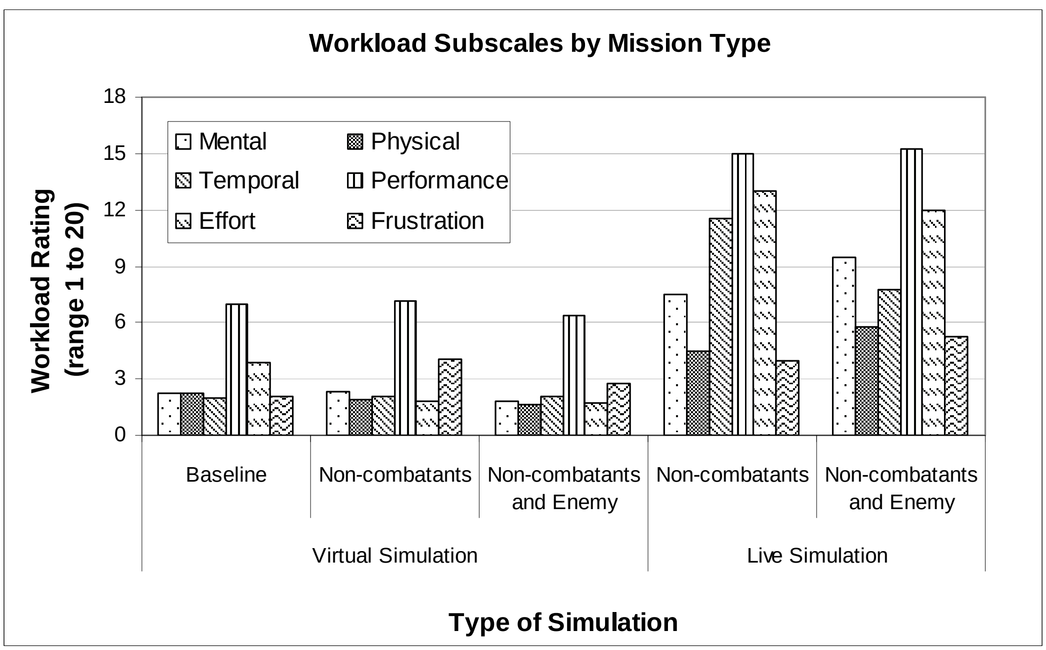

Figure 4. Workload subscales by mission type.

3.1.2 Crew Position (live simulation only)

Data for crew position were collected for the live vehicle only. Table 4 shows data for workload by crew position. Overall workload for the gunner was higher than for the driver. This comes mainly from the larger workload levels for the performance and (especially) effort subscales.

Table 4. Workload by crew position.

Position	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Driver (n-4)	8.00	5.25	9.75	13.25	6.00	5.00	47.25
Gunner (n=4)	9.00	5.00	9.50	17.00	19.00	4.25	63.75

One might expect that workload of gunners and drivers would be affected by mission. That is, when only non-combatants were present, the driver had to drive and (to the extent possible) identify personnel, whereas the gunner had to identify personnel and engage BLOS targets. However, in the trials when enemy were present, the gunner had to scan for personnel, engage threats, and engage BLOS targets, thus increasing workload. Tables 5 and 6 examine workload by condition and crew position. The hypothesis is not quite confirmed, in that in the non-combatants-only trials (see table 5), gunners had a slightly higher overall workload than drivers (because of differences in performance and effort workload), although drivers' mental, physical, temporal, and frustration workloads were higher. However, in the trials where non-combatants and enemy were present (see table 6), gunners had a far higher overall workload than drivers, thus showing the added workload when gunners were scanning for personnel and engaging threats.

Table 5. Workload by crew position by mission (non-combatants only).

Position	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Driver (n=2)	10.00	6.00	13.00	11.50	6.00	6.50	53.00
Gunner (n=2)	5.00	3.00	10.00	18.50	20.00	1.50	58.00

Table 6. Workload by crew position by mission (non-combatants and enemy).

Position	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Driver (n=2)	6.00	4.50	6.50	15.00	6.00	3.50	41.50
Gunner (n=2)	13.00	7.00	9.00	15.50	18.00	7.00	69.50

3.1.3 Autonomous Versus Manual Driving Mode (live simulation only)

Since the high-speed (20-mph) trial was conducted only in the manual driving mode, comparison between driving modes was only conducted in the low-speed (12-mph) trials. Table 7 presents

data for workload by driving mode. There is very little difference in overall workload between autonomous and manual driving. Temporal workload is actually more than five points higher in the autonomous mode.

Table 7. Workload by driving mode.

Position	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Autonomous (n-4)	7.50	4.50	11.50	15.00	13.00	4.00	55.00
Manual (n=2)	8.50	4.50	6.00	15.50	13.00	4.00	53.50

However, workload by driving mode should be affected by crew position. That is, driver workload should be reduced more in the autonomous mode than should gunner workload. Tables 8 and 9 examine workload by driving mode and crew position. Surprisingly, driver workload actually increases in the autonomous mode, especially for mental and temporal workload. One possible reason for this finding is that it is difficult to control the speed of the CAT in the auto-pilot mode. The mission required instances when the driver wanted to "creep," which was much easier in the manual mode than in auto-pilot. Gunner workload decreases in the autonomous mode, especially for mental workload. Perhaps in the autonomous mode, the gunner offloads some workload onto the driver, since the driver should have fewer driving responsibilities. Perhaps the driver is expected to assume more scanning responsibilities during autonomous driving. Admittedly, this is a speculation derived from a very small number of observations. Figure 5 provides a comparison of workload by driving mode across crew position.

Table 8. Workload by driving mode by crew position: driver.

Position	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Autonomous (n-2)	10.00	6.00	13.00	11.50	6.00	6.50	53.00
Manual (n=1)	7.00	5.00	8.00	15.00	6.00	4.00	45.00

Table 9. Workload by driving mode by crew position: gunner.

Position	Mental Workload	Physical Workload	Temporal Workload	Performance Workload	Effort Workload	Frustration Workload	Total Workload
Autonomous (n-2)	5.00	3.00	10.00	18.50	20.00	1.50	58.00
Manual (n=1)	14.00	4.00	4.00	16.00	20.00	4.00	62.00

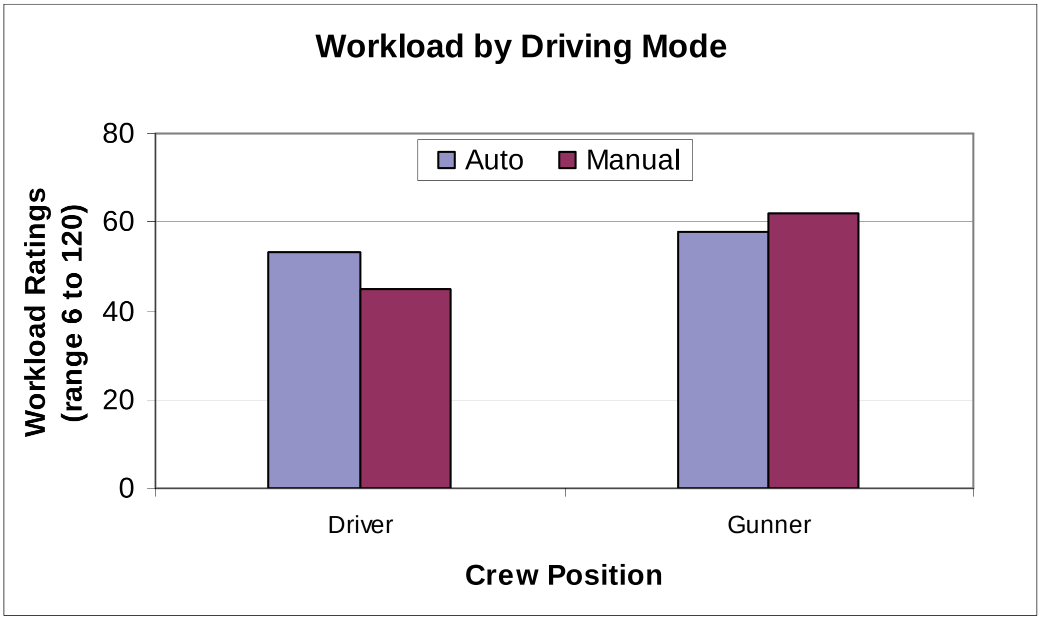

Figure 5. Workload by driving mode.

3.1.4 Driving Speed (live simulation only)

Overall workload was slightly higher in the higher speed condition in the manual driving mode. This was mainly because of higher ratings on the physical, temporal, frustration scales. This makes sense since physical actions, such as steering, would have to be done faster (temporal) during higher speed and would thus increase those aspects of workload. If actions seemed to have to taken place too quickly, that could lead to more frustration.

As shown in table 10, autonomous driving did not reduce workload; in fact, workload was slightly higher during autonomous driving. This resulted from higher temporal workload in the autonomous condition, suggesting that things seemed to happen faster in the autonomous mode. In addition, the increased workload may be attributable to the driver acting as systems monitor, which tends to increase cognitive workload primarily because of attention demands.

Table 10. Driving speed by driving mode.

Speed and Driving Mode	Mental	Physical	Temporal	Performance	Effort	Frustration	Total
12 mph & Autonomous (n=4)	7.50	4.50	11.50	15.00	13.00	4.00	55.50
12 mph and Manual (n=2)	10.50	4.50	6.00	15.50	13.00	4.00	53.50
20 mph and Manual (n=2)	8.50	7.00	9.50	15.00	11.00	6.50	57.50

3.2 Stress

3.2.1 Virtual Versus Live Simulation and Mission

Tables 11 and 12 present stress data for the two types of simulations and missions. Stress was higher for live simulation during both types of missions, although still rather low on a ten-point scale. There was very little difference in stress between the two mission types. There was no difference between mission types in live simulation and a small difference suggesting that the higher threat mission was slightly less stressful than the non-combatant condition in virtual simulation. This is similar to the workload data.

Table 11. Stress in virtual simulation by mission.

Mission	Physical Stress Level	Mental Stress Level
Baseline (n=16)	1.19	1.31
Non-combatants only (n=14)	1.21	1.36
Non combatants and enemy (n=19)	1.16	1.32

Table 12. Stress in live simulation by mission.

Mission	Physical Stress Level	Mental Stress Level
Baseline (NA)	NA	NA
Non-combatants only (n=4)	2.75	3.25
Non combatants and enemy (n=4)	2.75	3.24

3.2.2 Crew Position (live simulation only)

Table 13 shows data for stress by crew position. Stress was slightly greater for the gunner than for the driver.

Table 13. Stress by crew position.

Position	Physical Stress Level	Mental Stress Level
Driver (n=4)	2.50	3.25
Gunner (n=4)	3.00	3.25

As with workload, tables 14 and 15 show stress by crew position by mission. Also as with workload, in the trials when only non-combatants were present, stress was similar between positions, with higher physical stress for gunners and mental stress for drivers. However, when the enemy were present as well, both physical and mental stress were higher for gunners.

Table 14. Stress by crew position by mission (non-combatants only).

Position	Physical Stress Level	Mental Stress Level
Driver (n=2)	2.50	3.50
Gunner (n=2)	3.00	3.00

Table 15. Stress by crew position by mission (non-combatants and enemy).

Position	Physical Stress Level	Mental Stress Level
Driver (n=2)	2.50	3.00
Gunner (n=2)	3.00	3.50

3.2.3 Manual Versus Autonomous Driving (live simulation only)

Since the high-speed (20-mph) trial was run in the manual driving mode only, this comparison involved only the low-speed (12-mph) trials. Table 16 presents data for stress by driving mode. Stress was slightly greater in the autonomous mode. Tables 17 and 18 and figure 6 show stress by driving mode for each crew position. Physical stress was slightly higher for the driver in the manual mode, but mental stress was slightly higher in the autonomous mode, as was workload. For the gunner, both types of stress were higher in the manual mode, which suggests an off-loading of responsibility to the driver in autonomous driving mode.

Table 16. Stress by autonomous versus manual driving.

Driving	Physical Stress Level	Mental Stress Level
Autonomous (n=4)	2.75	3.25
Manual (n=2)	2.00	2.50

Table 17. Stress by autonomous versus manual driving: driver.

Driving	Physical Stress Level	Mental Stress Level
Autonomous (n=2)	2.50	3.50
Manual (n=1)	3.00	3.00

Table 18. Stress by autonomous versus manual driving: gunner.

Driving	Physical Stress Level	Mental Stress Level
Autonomous (n=2)	3.00	3.00
Manual (n=1)	1.00	2.00

3.2.4 Driving Speed (live simulation only)

Since high speed driving was done only in the manual mode, the following data are for manual mode only. Table 19 shows data for stress by driving speed and figure 7 depicts the relationship between stress and speed. As expected, stress was higher at higher speeds, with mental stress being higher than physical stress in both speed conditions.

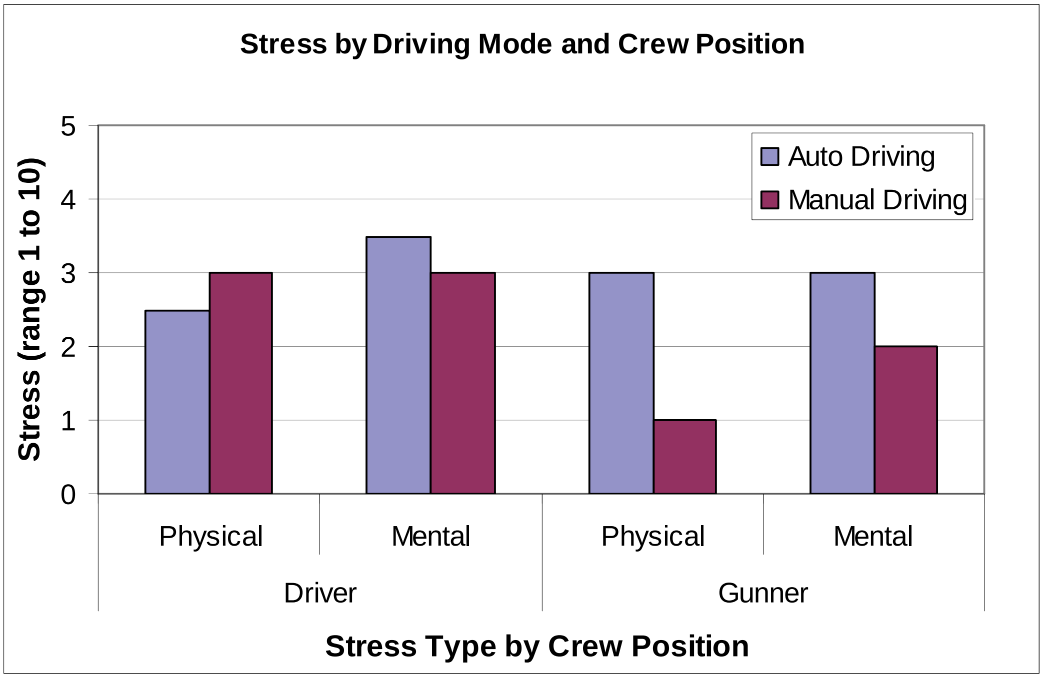

Figure 6. Stress by driving mode and crew position.

Table 19. Stress by driving speed.

Speed	Physical Stress Level	Mental Stress Level
12 mph (n=2)	2.00	2.50
20 mph (n=2)	3.50	4.00

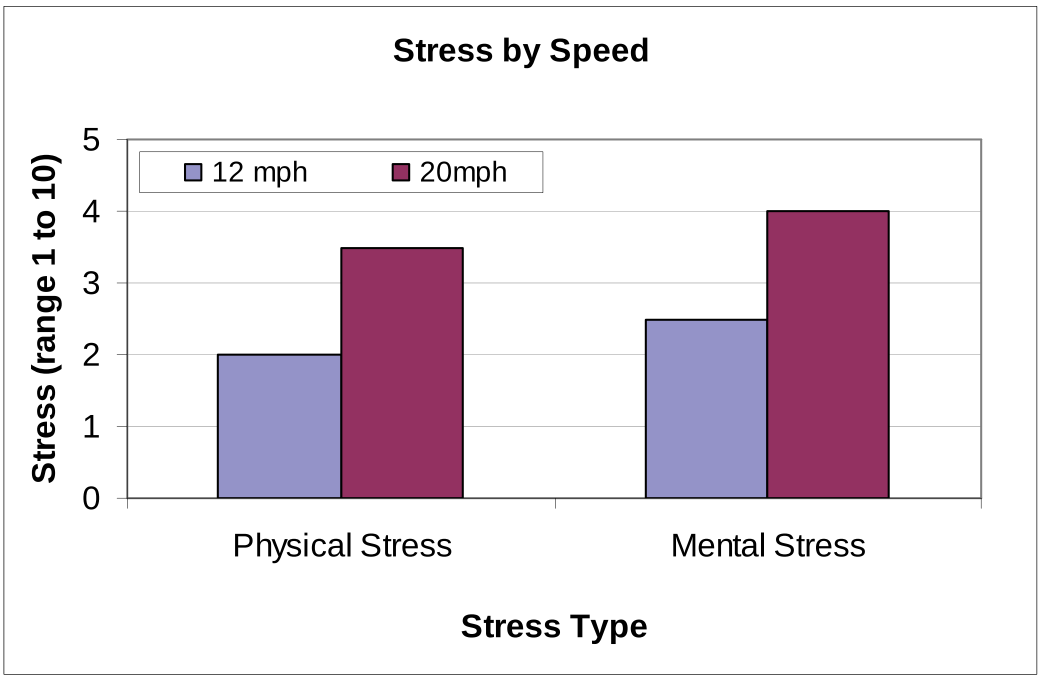

Figure 7. Stress by speed.

4. Discussion

Concerning the first objective, comparing live and virtual workload and stress, both workload and stress were higher in the live versus the virtual environment. This makes sense since the live vehicle may be liable to mishaps and bears closer attention, whereas a virtual one does not. Thus, the virtual simulation may not have provided the same realism level of vehicle mishap as the live simulation. This finding is also supported by the analyst's observations that vehicles moved faster in the virtual simulation than in the live environment. Thus, differences between workload and stress in a live versus virtual mode appear to be specific to the task performed. In a task involving driving, virtual simulation does not appear to provide a realistic assessment of workload or stress.

Concerning the second objective, involving workload and stress by type of mission, there were very few differences in workload and stress as a function of the type of mission. Apparently, looking for personnel, whether merely civilians (non-threats) or mixed threat and non-threat, is roughly equivalent in workload, especially when one does not know whether threats are present. The types of tasks (scanning the environment and driving) are similar in either mission, since one must be alert for potential threats in either case. In the live simulation, mental, physical, and frustration workloads were slightly higher in the condition where there were enemy targets, which suggests that identifying and servicing threats required slightly more thinking (to confirm a threat), action (to engage enemy personnel), and frustration (perhaps in uncertainty that an object engaged was a threat. However, it does not appear that workload or stress for either of the two missions severely taxed Soldier capabilities.

Concerning the third objective, examining workload and stress by driving mode, it appears that although workload was about the same in both driving modes, participants found the autonomous mode more stressful. This higher stress suggests that controlling vehicle speed may have been more difficult in the autonomous mode. The autonomous mobility mode had only a single speed setting, and the vehicle accelerated to that speed and tried to maintain it. A large part of the experiment involved cresting hills to scan the area ahead of the vehicle. In the autonomous mode, the driver had to keep stopping and starting the autonomous mode in order to simulate "creeping" forward. In fact, temporal workload was higher in autonomous mode, suggesting that participants spent more time monitoring vehicle movement. Further, since gunner workload decreased in the autonomous mode, perhaps the gunner offloaded responsibilities to the driver. The driver, however, perhaps because of an inability to easily control speed, felt the need to monitor vehicle movement and assume additional scanning responsibilities as well. It seems that the potential benefit of automation to reduce workload and free operators for other tasks does not appear to be realized in this particular research. These results are different from Experiment 2 in

RUX06, where autonomous driving reduced workload. One possible explanation for these different results posited by Nunez (2006) was that Experiment 6 involved re-planning in a secure environment (i.e., with no enemy threat). Therefore, it would be less risky to pay more attention to re-planning and less to what was happening outside the vehicle in Experiment 2. In the current experiment, with an enemy threat, Soldiers wanted to decelerate the vehicle at the crest of a hill or when rounding a bend. Autonomous driving only allowed a constant speed and a course to be set. The vehicle had to be started and stopped to adjust speed in route, thus perhaps adding workload not required in Experiment 2.

Concerning the fourth objective, workload and stress by position, workload and stress were slightly higher for gunners overall, but this was greatly affected by mission type. That is, in the trials when enemy were present, the workload (and to a lesser extent stress) for gunners was much higher than for drivers (and also much higher than gunners' workload in trials when civilians only were present). The increased workload for gunners in the trials when enemy are present is likely attributable to their having to simultaneously scan for personnel, distinguish civilians from enemy, and engage the enemy personnel. This finding was different from that of Mitchell et al. (2004) but again could be attributable to mission differences. In the IMPRINT model, the assumption was that the driver was driving constantly, whereas the gunner only had to occasionally perform his task. In the mission when an enemy threat was present, the gunner had to constantly scan for civilian personnel and enemy and engage the enemy when present. However, even in the more demanding mission, workload for the gunner was only about 58% of the maximum possible workload, and thus it appears within the capabilities of the Soldier to perform.

Higher driving speed also resulted in higher workload and stress than lower speeds. Tasks, whether driving, scanning, or engaging, were performed faster at higher vehicle speed. This was manifested particularly in physical workload (harder physical work) and temporal workload (less time to do tasks). However, even at the higher driving speed, workload was less than half the maximum possible workload and was thus likely well within the capabilities of the Soldier.

These results, although based on a small sample size, suggest that workload and stress are very task specific. When the task is operating a moving vehicle and scouting for personnel (civilians, enemy, or both), workload and stress were higher in a live environment. Also, autonomous driving did not reduce workload, again, perhaps because of an inability to adjust speed in this mode and offloading of work by the gunner in the autonomous driving condition. Also, contrary to previous research, gunners had higher workloads than drivers in this study, particularly when enemy targets were present, perhaps because gunner tasks were constant in this study.

This research suggests that examination of decision aids or CABs such as autonomous driving should be performed during different conditions, such as live and virtual simulation. A decision or performance aid may prove effective in some conditions but not others, and this information

may be useful in judging the effectiveness of an aid or under what conditions it should be employed.

5. References

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Appendix A. Measures

NASA TLX Workload Assessment Instructions

We are interested in the "workload" you experienced during this scenario. Workload is something experienced individually by each person. One way to find out about workload is to ask people to describe what they experienced. Workload may be caused by many different factors and we would like you to evaluate them individually. The set of six workload rating factors was developed for you to use in evaluating your experiences during different tasks. Please read them. If you have a question about any of the scales in the table, please ask about it. It is extremely important that they be clear to you.

Definitions

Title	End Points	Descriptions
MENTAL DEMAND	Low / High	How much mental and perceptual activity was required (that is, thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	Low / High	How much physical activity was required (that is, pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	Low / High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	Poor / Good	How successful do you think you were in accomplishing the goals of the task? How satisfied were you with your performance in accomplishing these goals?
EFFORT	Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	Low / High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

We want you to evaluate workload in two different ways. First, rate the workload on each factor on a scale. Each scale has two end descriptions, and 20 slots (hash marks) between the end descriptions. Place an "x" in the slot (between the hash marks) that you feel most accurately reflects your workload.

Next, we want you to compare the various workload factors. This comparison is a technique developed by NASA to evaluate the relative importance of the six workload sources you used to rate the workload you experienced. The procedure is simple: you have a sheet with a series of pairs of workload sources (for example, Effort vs. Mental Demands). We want you to choose which of the sources was more important to your experience of the workload in the task that you performed. You will fill out a separate sheet for each task.

For each pair of sources, circle the source that is the more important contributor to the workload for the specific task you are rating. For example, for the first comparison, if effort contributes to workload more than performance, circle effort.

After you have finished the entire series, we will be able to use the pattern of your choices to create a weighted combination of ratings into a summary workload score.

We ask you to evaluate your workload for this scenario. This includes all the duties involved in your job (e.g., preparing your workstation, using displays and controls at your workstation).

Participant ID:_____ Date:_______ Time:_______ Experiment:______ Condition:______

TLX Workload Scale

Please rate your workload by putting a mark on each of the six scales at the point which matches your experience.

Mental Demand

Very Low Very High

Physical Demand

Very Low Very High

Temporal Demand

Very Low Very High

Performance

Very Poor Very Good

Effort

Very Low Very High

Frustration

Very Low Very High

Participant ID:_____ Date:_______ Time:_______ Experiment:_______ Condition:______

Subjective Stress Rating Scale

1. The scale below represents a range of how PHYSICALLY stressful the mission might be. Check the block indicating how PHYSICALLY stressful the mission you just participated in was.

Task	Not at All Stressful 1	2	3	4	5	6	7	8	9	Most Possible Stress 10
a. Overall stress										

2. The scale below represents a range of how MENTALLY stressful the mission might be. Check the block indicating how MENTALLY stressful the mission that you just participated in was.

Task	Not at All Stressful 1	2	3	4	5	6	7	8	9	Most Possible Stress 10
a. Overall stress										

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